CHAPTER 39
PATIENT RADIATION DOSE MANAGEMENT

PATIENT DOSE DESCRIPTION

Estimation of Patient Dose

- Three Ways:
  - Entrance Skin Dose (ESE)
  - Mean Marrow Dose (MMD)
  - Genetically Significant Dose (GSD)

ESE

- X-ray exposure to the skin
- Most often is referred to as the *patient dose*
- *Expressed in:* mR
- It is used widely
  - *Rationale:*
    - Easy to measure
    - Reasonably accurate estimates can be made
- Three Methods of Estimation
  - Use of TLD
  - Use of nomogram
  - Know the output intensity for at least one operating condition
- *Fluoroscopy:* difficult to estimate

For the average fluoroscopic examination, one can assume an ESE of 4 R/min!

Gonadal Dose

- It is important because of possible genetic responses to medical x-ray exposure

Bone Marrow

- The target organ believed responsible for radiation-induced leukemia

Patient radiation dose is expressed as entrance skin exposure, gonadal dose & bone marrow dose!

MMD

- Average radiation dose to the entire active bone marrow
- Estimated from ESE

DISTRIBUTION OF ACTIVE BONE MARROW IN ADULTS

Anatomic Site	Percentage of Bone Marrow
Head	10
Upper limb girdle	8
Sternum	3
Ribs	11
Cervical vertebrae	4
Thoracic vertebrae	13
Lumbar vertebrae	11
Sacrum	11
Lower limb girdle	29
Total	

GSD

- Average gonadal dose given to members of the population who are of childbearing age
- The gonad dose that, if received by every member of the population, would produce the total genetic effect on the population as the sum of the individual doses actually received
- *Formula:*

$$GSD = \frac{\sum DN_x P}{\sum DN_t P}$$

- *Annual Dose:* 100 mrad/yr (in US)

PATIENT DOSE IN SPECIAL EXAMINATION

Dose in Mammography

- *ESE:* 800 mR/view
- *Midline of the Breast:* 100 mrad

Glandular Dose

- *Symbol:* D_g
- Average radiation dose to glandular tissue
- It is approximately 15% of the ESE
- *Contact Mammography:* not exceed 100 mrad/view
- *With Grid:* not exceed 300 mrad/view

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Dose in Computed Tomography

- Tissue Dose: approximately equal to the average fluoroscopic dose
- It is approximately 50% of the ESE for body CT
- *Head Imaging:* 3000-5000 mrad
- *Body Imaging:* 2000-4000 mrad
- *Effective Dose:* 1000 mrem or 10 mSv
- *Pitch of 1.0:1:* same patient dose
- *Higher Pitch:* reduced patient dose
- *Lower Pitch:* increased patient dose
- *Formula:*

$$\text{Patient Dose} = k\ \frac{IE}{\sigma^2 w^3 h}$$

- *Low Noise, High Resolution, Other Factors Remain Constant:* higher patient dose
    -

Sigma

- *Symbol:* σ
- It is noise
- Equivalent to quantum mottle in screen-film radiography
- It represens random statistical variations in CT numbers

Pixel Size

- *Symbol:* w
- One of the determinants of spatial resolution

Beam Width

- *Symbol:* h

A reduction in the noise or beam width, while other factors remain constant, increases patient dose!

Multislice Spiral CT

- It results in lower patient dose than conventional step-and-shoot CT
    - *Rationale:* fewer tails are seen on the dose profile for a given volume of tissue

Penumbra

- The dose profile tail

The higher the multislice value, the lower the patient dose will be!

REDUCTION OF UNNECESSARY PATIENT DOSE

Unnecessary Examination

- Routine examination should not be performed when there is no precise medical indication

Hospital Admission

- Chest x-ray examinations should not be performed for routine hospital admission when no clinical indication of disease is found

Preemployment Physical

- Chest & lower back x-ray examination are not justified
    - *Rationale:* the knowledge gained about previous injury or disease is nil

Periodic Health Examination

- It should not include x-ray examination for asymptomatic patient, especially fluoroscopic examination

Emergency Room CT

- Overutilization must be controlled
    - *Rationale:* rapidly rising population effective dose

Whole-Body Multislice Spiral CT Screening

- This should not be done
    - *Rationale:* radiation dose is too high

Repeat Examination

- *Repeat Rate:*
    - All examination – 10%
    - Busy Hospital – should not exceed 5%
- *Highest Repeat Rate Examination:* lumbar, thoracic & abdomen
- *Caused:*
    - Radiologic technologist error

        - Most common
    - Equipment malfunction
- *Responsible For Repeats:*
    - Poor radiographic technique
        - primary
        - Too light or too dark
    - Motion
    - Improper collimation
    - Dirty screens
    - Improperly loaded cassettes
    - Light leaks
    - Chemical fog
    - Artifacts
    - Wrong projection
    - Improper patient preparation
    - Grid errors
    - Multiple exposures

It should never be necessary to repeat a digital radiographic examination!

Radiographic Technique

- Higher kVp: reduces mAs
    - Results:
        - Reduced patient dose
        - Too low contrast

Proper Collimation

- Essential to good radiographic technique
- Results:
    - Reduced effective dose
    - Improved image quality
    - Enhance contrast resolution
        - *Rationale:* scatter radiation is reduced

Image Receptor

- General Radiography: 400-speed system
- Fast Screens
    - *Result:* quantum mottle
- *Digital Radiographic IR:* faster than screen-film

Patient Positioning

- Upper Extremities & Breast Examination
    - *Seated Position:* the useful beam should not intercept the gonads
    - *To Avoid:* patient in lateral position with a protective apron

Specific Area Shielding

- *Indicated:* when a particularly sensitive tissue or organ is in or near the useful beam
- *Two Types:* contact shield & shadow shield

Contact Shield

- Shields that are flat & are placed directly on the patient's gonads
- *Examples:*
    - Lens shield
    - Gonads shield – can be of shadow type
    - Breast shield – during scoliosis examination

Shadow Shield

- Shields that is suspended over the region of interest
- It casts a shadow over the patient's reproductive organs
- More acceptable for use with adult patients
- Improper Positioning of Shield
    - *Results:*
        - Repeat examinations
        - Increased patient dose
- *Application:* surgery

Main Points of Gonadal Shielding

- It should be considered for all patients, especially children & those who are potentially reproductive. As an administrative procedure, this would include all patients younger than 40 years of age & perhaps even older men
- It should be used when the gonads lie in or near the useful beam
- Proper patient position & beam collimation should not be relaxed when gonads shields are in use
- It should used only when it does not interfere with obtaining the required diagnostic information

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THE PREGNANT PATIENT

Radiobiologic Considerations

- Time dependence
  - *1st 2 weeks:*
    - Least hazardous
    - *Biologic Response:* resorption of the embryo & no pregnancy
  - *2nd-10th weeks:* major organogenesis
    - The major organ system of the fetus is developing
    - *Biologic Response:* congenital malformation
  - *2nd & 3rd Trimester:*
    - *Principal Response:* malignant disease during childhood
- Dose Dependence
  - *Previously Noted Effects:* 200 rad
  - *Spontaneous Abortion:* < 25 rad
    - During 1st 2 weeks
  - Congenital Abnormalities
    - *Fetal Dose:* 10 rad

Relative Risk of Radiation-Induced Childhood Malignancy

- 1st Trimester: 5-10
- 3rd Trimester: 1.4
- *Overall Relative Risk:* 1.5

Patient Information

- One should never knowing examine a pregnant patient with x-rays unless a documented decision to do so has been made
- *Administrative Protocols:* elective booking, patient questionnaires & posting

Elective Booking

- The most direct way to ensure against irradiation of an unsuspected pregnancy
- It requires that clinician, radiologist or radiologic technologist determine the time of the patient's previous menstrual cycle

Patient Questionnaires

- An alternative procedure to have the patient herself indicate her menstrual cycle
- *Example:* x-ray consent

Posting

- Posting signs of caution in the waiting room

We meet our responsibility to the pregnant patient by posting signs in the waiting room!

Responsibility of Radiology Service When Pregnant Patient is Irradiated

- Estimate the fetal dose
  - Medical physicist
- Determine the stage of gestation
  - Referring physician & radiologic technologist

PATIENT DOSE TRENDS

Human Radiation Exposure

- *Natural:* 3 mSv/yr
- *Medical Imaging:* 3.2
- *Total:* 6.3 mSv/yr